TERRESTRIAL ECOLOGICAL UNIT INVENTORY (TEUI) -GEOSPATIAL TOOLKIT

John Lane
Soil Scientist
USDA Forest Service, Northern Region
Custer National Forest
1310 Main St.
Billings, MT 59105
jrlane@fs.fed.us

Haans Fisk
USDA Forest Service
Remote Sensing Applications Center
2222 West 2300 South
Salt Lake City, UT 84119

ABSTRACT

Terrestrial Ecological Unit Inventory (TEUI) endeavors to classify and map ecosystems based on environmental factors, including climate, landform, geology, vegetation, and soils. These inventories provide resource specialists with baseline information and serve as a core data layer in project planning, watershed analysis, and forest plan revision. The TEUI-Geospatial Toolkit accesses and combines the capabilities of remote sensing, geographic information system (GIS) technology, and raw computing power in an easy-to-use format, allowing TEUI specialists to formulate mapping concepts and digitize ecological units directly into GIS. This customized software application functions entirely within the Forest Service corporate hardware/software platform. Products generated by this toolkit utilize and are compatible with Arc/Info™, ArcView™, ERDAS Imagine™, Visual Basic™, Access™, Oracle™ databases, and the Forest Service's Natural Resource Information System Terrestrial Module (NRIS-Terra), as well as the National Soil Information System of the Natural Resource Conservation Service (NRCS). The TEUI-Geospatial Toolkit is helping modernize natural-resource inventory by providing specialists with tools to visualize, map, and interactively analyze terrestrial landscapes.

INTRODUCTION

Background

TEUI is one of the land-survey systems used by the Forest Service to classify and map ecosystems and provide baseline resource information so that local land planners can make informed and practical management decisions. TEUI stratifies landscapes into repeating ecological units based on abiotic factors of the physical environment and biotic variables like potential natural vegetation (PNV). According to Cleland et al. (1997), the purpose of a TEUI is to classify ecosystem types and map land areas that have similar management capabilities to a consistent standard throughout the national forest system lands (Winthers et al., 2001). TEUI products (maps, spatial and tabular databases, map-unit descriptions, ecological-type descriptions and interpretations) provide basic land-unit information that can be used in ecological and watershed assessments; burned area emergency rehabilitation (BAER), range-allotment plan updates, forest plan revisions, and project-level planning and analysis, as well as implementation and monitoring. Data collected through TEUI are stored and managed by the Natural Resource Information System Terrestrial Module (NRIS-Terra) and the National Soil Information System of the Natural Resource Conservation Service (NRCS).

The National Hierarchical Framework of Ecological Units is a land classification that provides a method for portraying terrestrial ecological units at multiple scales (Figure 1). It offers a way to stratify the Earth into progressively smaller and more homogeneous units and is deeply woven into the concept of TEUI. At the broadest level ecoregions are divided into subregions, landtype associations, and land units. Using these different scales, managers, scientists, and planners can address ecological concerns in an organized, strategic manner. For instance, landtype associations (landscape scale) are useful for forest or area wide planning and watershed analysis, whereas landtypes (land unit scale) are better suited for the project level to assist with resource analysis and on-the-ground planning.

The National Hierarchical Framework of Ecological Units

Planning and Analysis Scale	Ecological Unit	Purpose, Objectives, and General Use	General Size Range
Ecoregion Global Continental Regional	Domain Division Province	Broad applicability for modeling and sampling; Large area planning and assessment; International planning	Millions to ten thousands of square miles.
Subregion	Section Subsection	Strategic, multi-forest, statewide, and multi-agency analysis and assessment	Thousands to tens of square miles.
Landscape	Landtype Association	Forest or areawide planning and watershed analysis	Thousands to tens of acres.
Land Unit	Landtype Landtype Phase	Project and management area planning and analysis	Hundreds to less than ten acres.

Figure 1. The National Hierarchical Framework of Ecological Units defines appropriate scales for applying TEUI in ecosystem management.

Traditional inventory mapping methods rely heavily on aerial photography (Soil Conservation Service, 1993). Unfortunately, this medium presents problems when large areas are being mapped. Photo-derived maps often reflect the bias of photo interpreters, adversely affecting the consistency of the TEUI product. In addition, spatial landscape analyses are usually conducted only after mapping has been completed, rather than being integrated into the process. To fully utilize multiscale ecological information and share it within, as well as outside the agency, the Forest Service must collect consistent and continuous ecosystem baseline data, which is difficult to achieve using traditional methods.

Remote sensing, GIS technologies, and raw computing power have dramatically improved over the last few years and promise to make the TEUI process much more efficient and consistent. Therefore, resource and geospatial experts are revising protocols in the *Terrestrial Ecological Unite Inventory Technical Guide* and developing state-of-the-art tools to assist specialists. To address these tasks, a project team has been assembled, consisting of resource specialists from the Custer National Forest, TEUI coordinators, specialists from Washington Office and Regions 1 and 4, and personnel from the Remote Sensing Applications Center, was assembled and assigned the task. The team defined the project scope around TEUI mapping requirements and draft TEUI Technical Guide. The pilot application was developed in the context of an ongoing TEUI being conducted on the Custer National Forest. Some of the immediate utility of this application will be tested in conducting new TEUIs as well as updating existing land type level resource inventories.

This project proposes developing a prototype software application called the TEUI-Geospatial Toolkit (Figure 2). It is designed to facilitate TEUI mapping and support major aspects of natural resource inventory. Specifically, the TEUI toolkit makes use of advanced, machine-aided methods to process geospatial data, enabling resource specialists to formulate mapping concepts and efficiently delineate ecological strata directly into GIS. Products generated from this toolkit will function entirely within the corporate hardware platform, including Arc/Info™, ArcView™, Access™, Oracle™, and NRIS-Terra databases. The proposed toolkit will formulate more standardized, efficient, and cost-effective methods to complete TEUI surveys, specifically at the land type association and land type scales. It also has the capability of quickly generating 3-D perspective views and other visualization enhancements promoting better communication among internal and external cooperators.

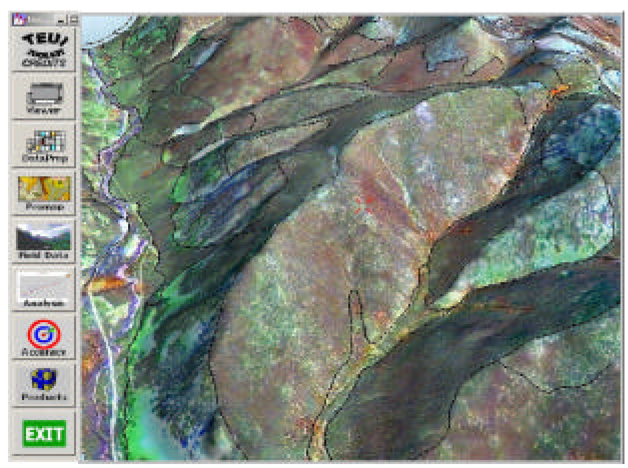

Figure 2. The TEUI-Geospatial Toolkit is a customized software application designed for landscape mapping.

Study Area

The inventory area chosen for this project is in the Beartooth Ranger District, in the Custer National Forest (Figure 3). The Beartooth area is located in south-central Montana and consists primarily of lands administered by the Forest Service. It includes parts of Carbon, Stillwater, Park, and Sweetgrass counties and lies within the boundaries of the Custer National Forest. Elevations range from around 6,000 to almost 13,000 feet above sea level. The landscape is composed of steep mountain slopes and glaciated plateaus that are dissected by deep canyons and stream valleys. Vegetation ranges from lower subalpine forest and mountain grassland to tundra and barren rock at higher elevations. Soil temperature regimes are frigid and cryic. The Beartooth Plateau is a unique alpine environment uncommon in the lower 48 states and has great ecological diversity.

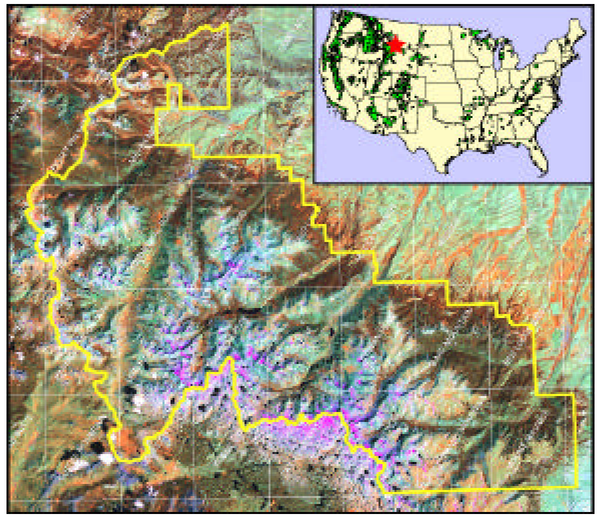

Figure 3. The study area is located on the Beartooth Plateau in the Custer National Forest.

TEUI-GEOSPATIAL TOOLKIT

Toolkit Design

The primary objective of this project is to develop tools to improve the efficiency of mapping landscapes and standardize final TEUI products. The toolkit has been divided into six sections each highlighting a major activity normally conducted during landscape stratification. The six divisions consist of data preparation, premapping, field sampling, analysis, accuracy assessment, and final products. Remote sensing and geospatial technology were identified as key ingredients to fulfill project objectives and promote collection of consistent and continuous resource information. The toolkit is programmed to manipulate various forms of data in a GIS environment specifically for the needs of TEUI. Figure 4 highlights three essential geospatial data layers needed to carry out core mapping goals of TEUI, including, digital elevation models (DEMs), Landsat Enhanced Thematic Mapper

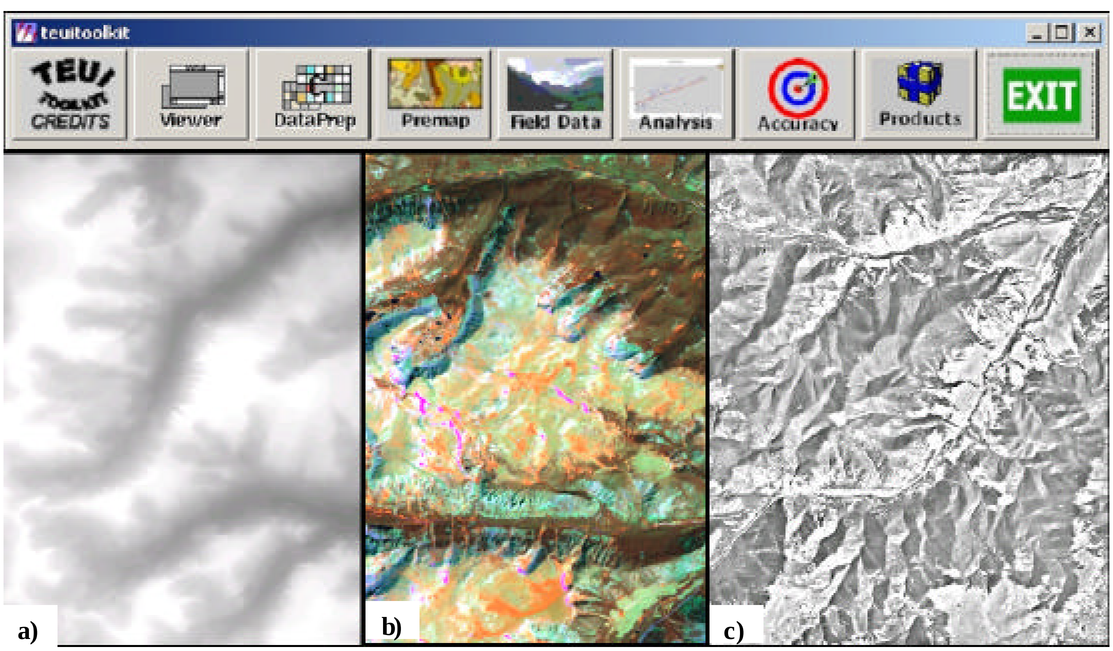

Figure 4. TEUI-Geospatial Toolkit modules and essential geospatial data layers: a, DEM at 10-meter spatial resolution; b, Landsat ETM satellite imagery at 30-meter multi-spectral and 15-meter panchromatic spatial resolution; c, DOQ at 1-meter spatial resolution.

(ETM) satellite imagery, and digital orthophoto quadrangles (DOQs). These essential geospatial data layers are readily available for most national forests or will be accessible within a few years.

The toolkit is engineered to operate on Forest Service corporate hardware and software. This application requires a high-end PC, such as the M41 or A60, to serve as the central processing unit and makes use of advanced raster and vector processing software, such as ERDAS Imagine™, Arc/Info™, and Access™. Using C++ and Visual Basic. This mapping program functions as a stand-alone package but seamlessly interacts with the various software programs to capitalize on resources and maximize efficiency. The toolkit guides users in advanced data processing techniques, including data loading, landscape visualization, heads-up digitizing, and spatial landscape analysis, all fundamental aspects of TEUI.

This project spans two fiscal years, 2002 and 2003. By the end of FY2003, a functional and tested prototype software application should be available to TEUI field units. During FY2002, priorities revolve around developing and testing the first three modules of the project: data preparation, premapping and field sampling. This first phase is well under way, and a stand-alone product may be available for distribution in the near future. During the second phase, project coordinators will evaluate and pursue the final three modules in the light of product feasibility, available workforce, and rigid time frames. Here are descriptions of the individual modules; revealing the ways they meet the data-processing needs of TEUI.

Data Preparation (FY2002)

The data preparation module provides resource specialists with the ability to quickly and easily import, store, and manage geospatial data sources needed for TEUI. One important feature is directing the user to national data warehouse websites, like the USFS geospatial data clearinghouse. Once linked to a standard clearinghouse, the user can quickly retrieve standardized data, such as cartographic feature files (CFF) and DEMs. After downloading, the toolkit will automatically import, compile, and prepare specified data for immediate use in TEUI. Figure 5 demonstrates downloading and preparing a set of DEMs on the pilot study area. In this example, the TEUI-Geospatial Toolkit completed the entire processing on a sample data set containing thirty 7.5-minute quadrangles in less than 10 minutes. It is important to note that the terminology is simplified in the graphical user interface so that resource specialists do not have to be experts in the remote sensing to take advantage of this technology. This easy-to-use and speedy data-retrieval system dramatically simplifies many technical aspects of loading and preprocessing information and makes spatial data available to greater numbers of resource scientists.

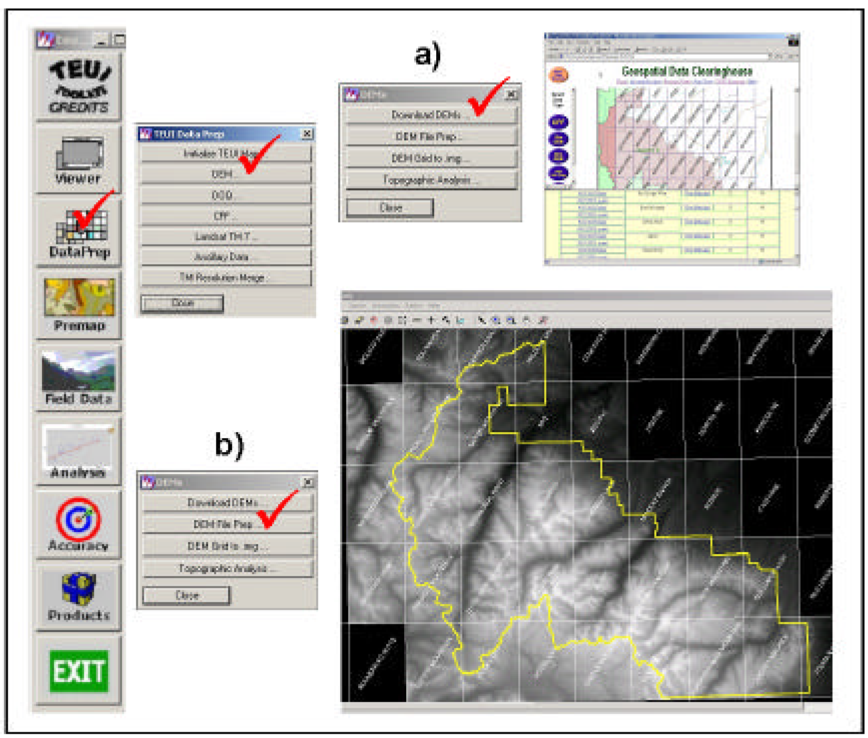

Figure 5. DEM processing is simplified and more efficient using the TEUI-Geospatial Toolkit. For example, the DEM interface: a, directs the user to a FGDC-compliant geospatial data clearinghouse to download standardized data layers; and b, automatically uncompresses, converts, mosaics, and reprojects data retrieved from the geospatial data clearinghouse as a batch process.

Another custom feature built into the toolkit is machine-assisted processing of geospatial data sets to provide additional information on landscapes. For example, DEMs are modeled to provide important topographic indices like aspect, slope, and curvature. These derived data layers are packaged as “button technology,” simplifying and standardizing basic processing techniques. However, some of the processing requires the operator to provide certain input. For these situations, the toolkit uses a step-by-step interface to guide the user through the process, obtain the necessary information, and generate additional data layers, such as high-resolution merged imagery (Figure 6).

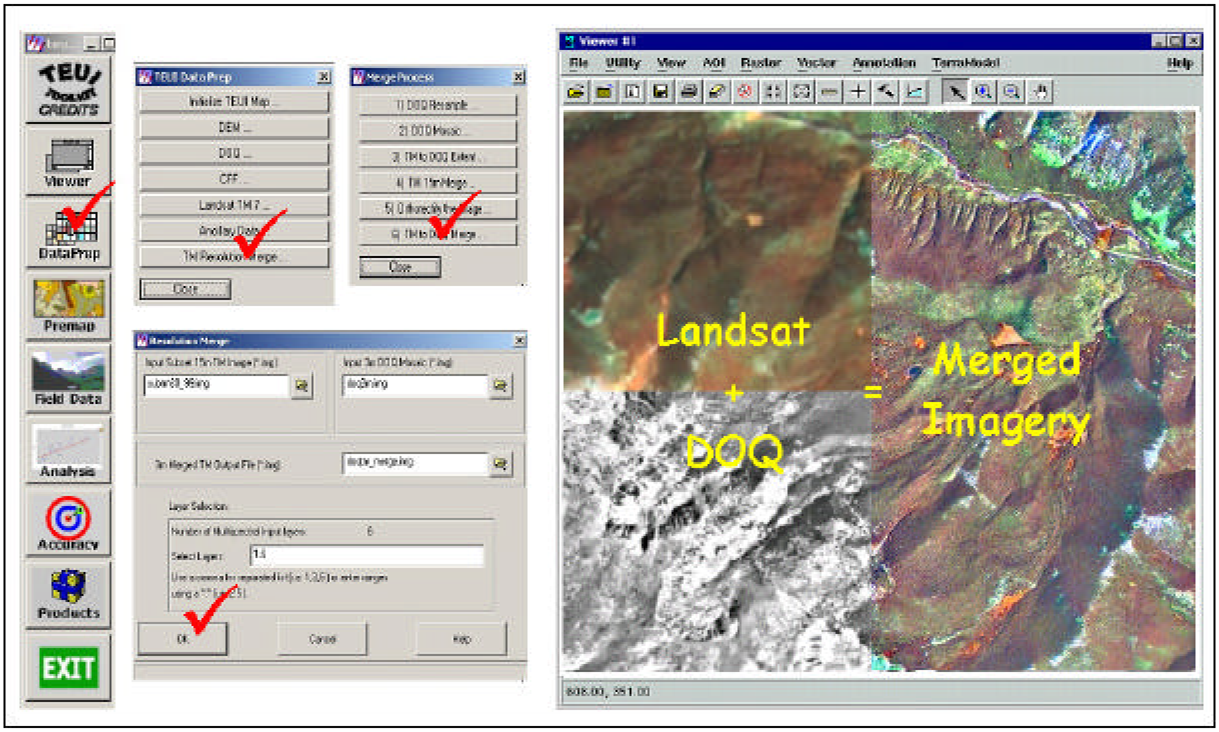

Figure 6. Machine–assisted processing creates high-resolution, merged Landsat and DOQ imagery with three-meter spatial resolution.

Premapping (FY2002)

The premapping module provides tools to assist TEUI resource specialists in classifying, mapping, and characterizing ecological units. The user can visualize the landscape, delineate mapping units directly into GIS, and statistically analyze the environmental variables of selected units. Visualization enhancements include terrain profiles, 3-D views, and flybys (Figure 7). Visualizing the landscape is critical when conducting TEUI and in most other resource areas. The toolkit provides interpreters with multiple perspectives of the landscape, allowing them to see individual components and develop an understanding on how ecosystems function and interact at varying scales.

Once the TEUI specialist develops a strategy for stratifying the landscape, the toolkit provides efficient ways to delineate map units directly into GIS, using heads-up, on screen digitizing (Figure 8). High-resolution imagery offers a backdrop for identifying and referencing map-unit boundaries. Depending on the interpreter’s preference, the backdrop may include a DEM hill-shade image, a high-resolution merged image, or even a stereo version, called an “anaglyph” image. One of the benefits of viewing imagery onscreen is that more than one resource specialist can be involved in the premapping effort, strengthening map unit concepts. The toolkit also comes equipped with special features for cleaning and building polygons minimizing some of the tedious tasks normally encountered with manual digitizing.

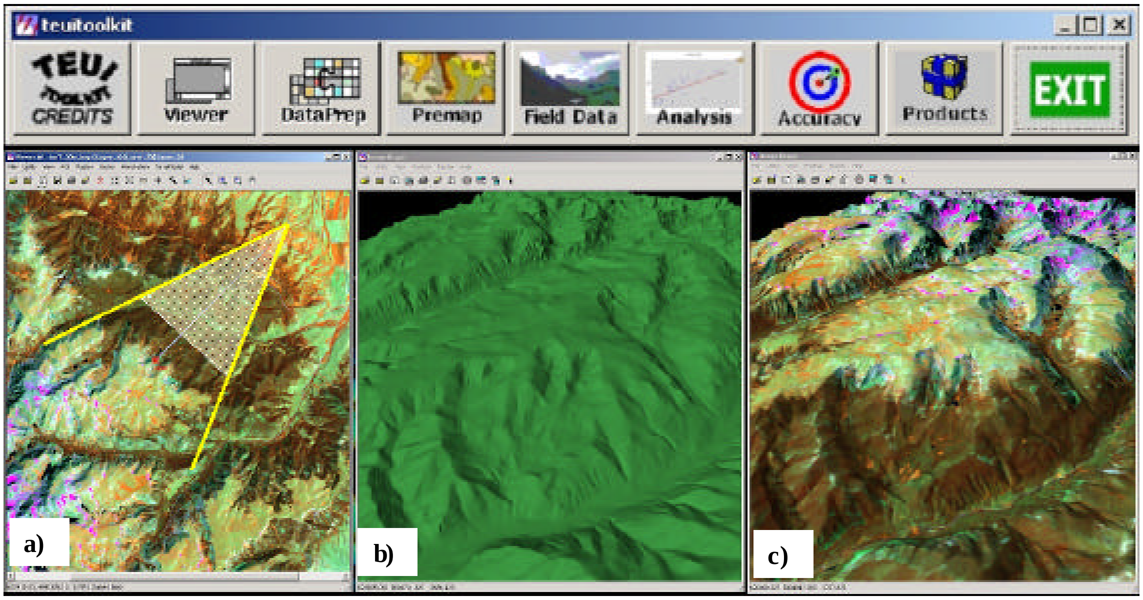

Figure 7. Viewing in 3-D is just one of the visualization capabilities available in the TEUI-Geospatial Toolkit: a, a 2-D viewer with interactive eye and target objects that alter the perspective; b, a view of the terrain; c, a view with Landsat TM-7 imagery draped over the terrain.

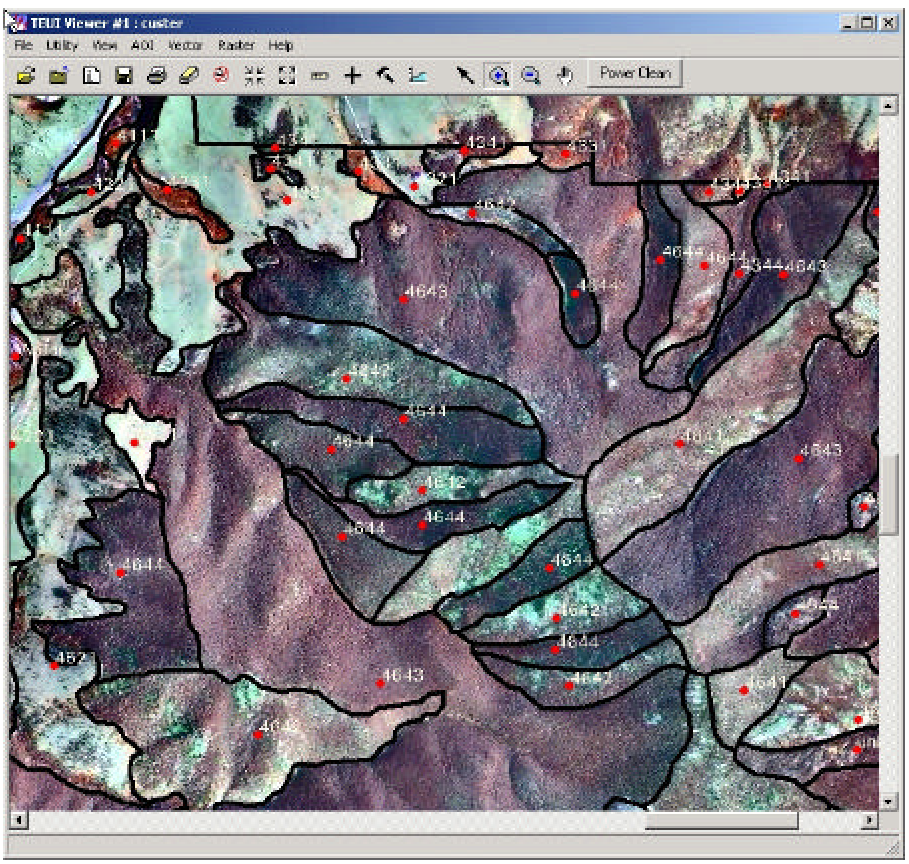

Figure 8. Heads-up digitizing land units directly into GIS using high-resolution imagery as a spatial reference.

Finally, the TEUI-Geospatial Toolkit includes a spatial landscape-analysis tool, which allows the specialist to retrieve environmental information about a selected set of polygons or map units. On the click of a button, selected polygons are automatically converted to a raster format and used to extract spatially explicit environmental data on a pixel-by-pixel basis. The extracted dataset provides the fundamental morphometric and biological information used to generate summary statistics, tabular and graphical reports (Figure 9). This analytical tool is invaluable in helping resource specialists convey mapping concepts and consistently document map unit characteristics.

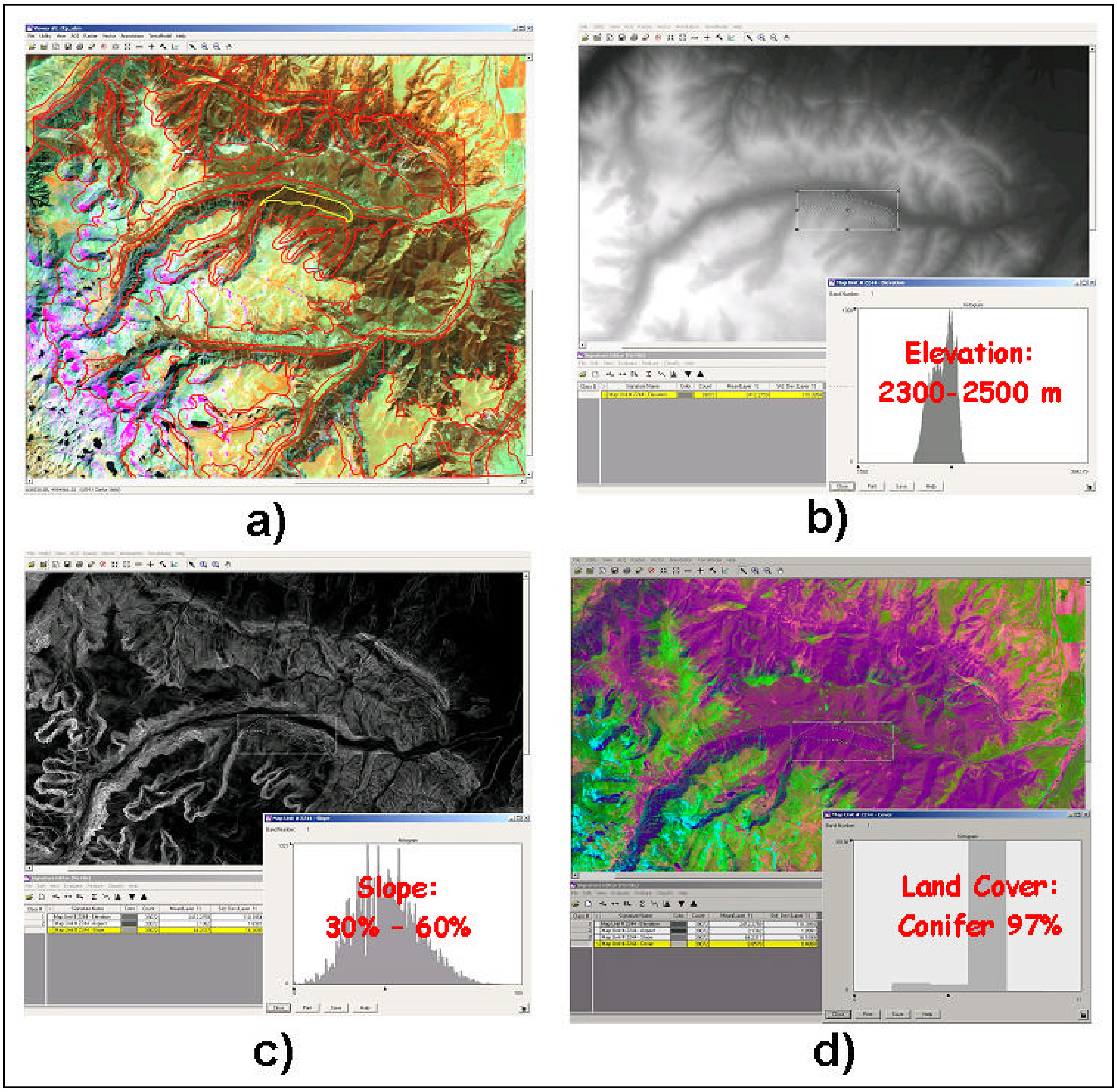

Figure 9. Selected polygons define zones of interest that query the environmental database and describe the areas' physical features: a, mapped polygons (in red) overlaid on Landsat TM-7 satellite imagery in which one polygon is currently selected (in yellow); b, elevation-frequency distribution curve of the selected polygon; c, slope-frequency distribution curve of the selected polygon; d, aspect-frequency distribution curve of the selected polygon.

The environmental data are stored in a master database, which is constructed using the toolkit. It contains a number of important variables including elevation, aspect, slope, vegetation, geology, average temperature, annual precipitation, and solar radiation. The climatological data models in the toolkit have a spatial resolution of 1 kilometer and were obtained free of charge on-line at www.daymet.org (Thornton et. al., 1997; Thornton et. al., 1999; and Thornton et al., 2000).

Field Sampling (FY2002)

The field sample module will provide TEUI specialists with an efficient way of selecting representative samples and assist in designing an efficient field-sampling strategy. Currently, representative samples are chosen by the interpreter and located onscreen in GIS. Roads, trails and terrain-roughness models provide the basis for conducting cost-distance analysis and help determine a logical sequence for site visitation. Once the sites are identified, standardized field sheets, or maps, are easily created with the TEUI-Geospatial Toolkit and used in the data collection effort. Figure 10 provides an example of a 1:24,000 custom map field sheet. In creating this map the user can specify backdrop imagery and the particular vector data products that will be most useful for field orientation. Once created, maps are simply printed on a plotter to obtain a hard copy.

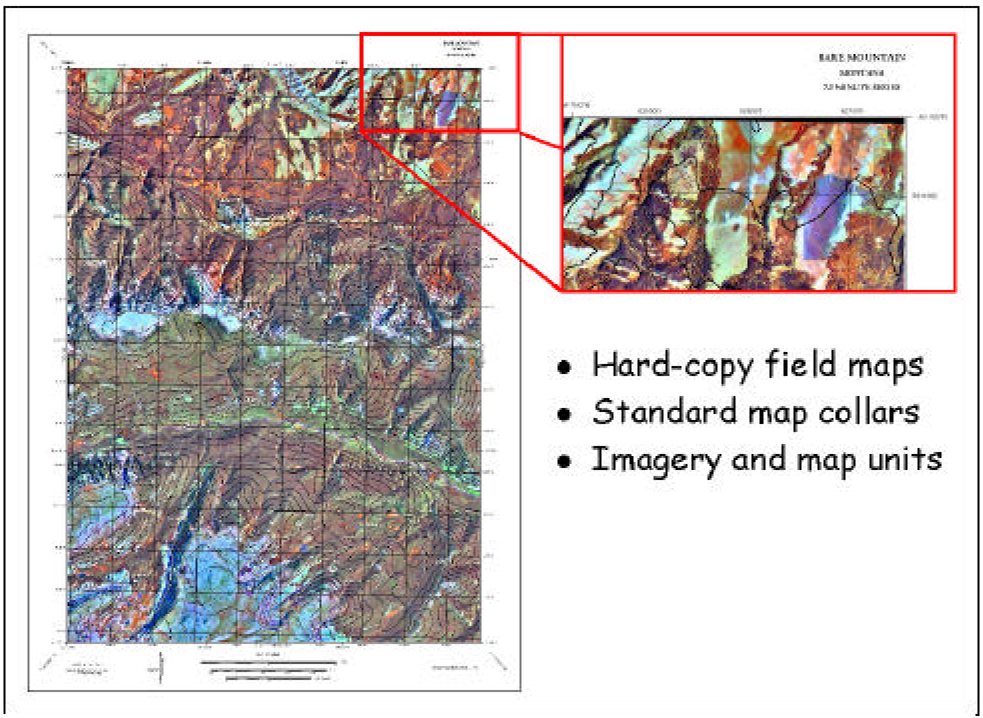

Figure 10. An example of a 7.5-minute field map.

Analysis (FY2003)

The analysis module will offer TEUI specialists the ability to summaries morphometric and biological data for the purpose of validating and refining map unit concepts and boundaries. In addition, this module will integrate geospatial data layers with recently collected field data for conducting a number of ecological analyses. Various landscape interpretations may also be generated, and if needed, displayed spatially over a rendered landscape and incorporated in project level planning.

Accuracy (FY2003)

The accuracy module will provide tools for conducting quality control to the TEUI. In direct support of the TEUI protocol, these assessment tools will help specialists validate the component composition of ecological map units and provide for an assessment of overall map accuracy. This module should add validity to the TEUI product and settle disputes over interpretive reliability.

Products (FY2003)

The products module will include tools to generate finalized TEUI products, standardized reports and published documents. Specific items may include maps, perspective views, block diagrams, ecological type and map unit descriptions, and landscape interpretations. These data products will be packaged and migrated to corporate databases like NRIS-Terra and National Soil Information System (NASIS).

CONCLUSIONS AND RECOMMENDATIONS

In summary, this TEUI-Geospatial Toolkit combines the capabilities of remote sensing, GIS technologies, and raw computing power in an easy-to-use format, allowing resource specialists to formulate mapping concepts and digitize ecological units directly into GIS. The toolkit is being developed as a push-button menu-driven application requiring minimal knowledge of remote sensing and GIS and functions within the Forest Service corporate hardware/software platform. The TEUI-Geospatial Toolkit possesses many benefits over traditional survey methods and has significant implications in conducting new inventories, as well as updating existing soil, vegetation, or other resource inventories in need of revision. Some of the benefits include appropriate use of existing geospatial data, interdisciplinary landscape stratification and mapping, concurrent spatial landscape analysis with resource mapping, efficient field sampling, consistent data products, direct links to corporate information systems like NRIS-Terra and significant cost savings on a local and national level. The TEUI-Geospatial Toolkit is helping modernizes natural resource inventory by providing resource specialists with tools to visualize, map, and interactively analyze terrestrial landscapes.

Although this toolkit has been designed specifically for TEUI specialists, the concept of customized toolkits can be redirected and focused on any number of different resource areas. Application of this prototype will enable the Forest Service to take full advantage of remote sensing and geospatial technologies and more efficiently produce desired products. Field units realize this potential and have already expressed a great deal of interest in pursuing the development of customized software applications to support BAER, forest health protection, streamlining the National Environmental Protection Agency process and project-level planning. We recommend that the National Forest Service use the TEUI-Geospatial Toolkit to conduct and update resource inventories and, in addition, support the development of customized software applications in other resource management areas.

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